УДК 616.711-007.29-053.1-089
https://doi.org/10.17816/PTORS745-14

A COMPARATIVE ANALYSIS OF THE SURGICAL TREATMENT OF PRESCHOOL CHILDREN WITH CONGENITAL SPINAL DEFORMATION AND ISOLATED HEMIVERTEBRA FROM THE COMBINED AND DORSAL APPROACHES

© *S.V. Vissarionov[1], A.R. Syundyukov[2], D.N. Kokushin[1], N.O. Khusainov[1], M.A. Khardikov[1]*

[1] The Turner Scientific Research Institute for Children's Orthopedics, Saint Petersburg, Russia;
[2] Federal Center for Traumatology, Orthopedics and Endoprosthetics, Cheboksary, Russia

■ For citation: Vissarionov SV, Syundyukov AR, Kokushin DN, et al. A comparative analysis of the surgical treatment of preschool children with congenital spinal deformation and isolated hemivertebra from the combined and dorsal approaches. *Pediatric Traumatology, Orthopaedics and Reconstructive Surgery*. 2019;7(4):5-14. https://doi.org/10.17816/PTORS745-14

Received: 12.07.2019 Revised: 01.12.2019 Accepted: 09.12.2019

Background. Currently, there are many studies on the evaluation of the results of surgical intervention and the comparative analysis of various surgical techniques for treating children with congenital spinal deformities. However, there is no consensus regarding the choice of surgical access to the abnormal vertebra that considers the duration of surgery, the volume of intraoperative blood loss, the degree of correction achieved during the intervention, the length of metal fixation, and the preservation of the result in the long-term observation period.
Aim. The goal is to identify the advantages and disadvantages of the dorsal and combined approaches to the surgical treatment of preschool children with congenital deformities of the thoracic and lumbar spine against the background of an isolated violation of the vertebral formation.
Materials and methods. A retrospective analysis of 56 patients under the age of five with congenital spinal deformities and a history of an isolated hemivertebra in the thoracic and lumbar regions who underwent one-stage hemivertebral extrusion from a dorsal approach (1st group: $n = 30$) or from a combined approach (2nd group: $n = 26$) was conducted.
Results. All patients showed improvement in the sagittal and frontal profiles of the spine. However, during separation in the first group of patients, a progression of the kyphotic component of the deformity in the lumbar spine from −19° to −8° was noted, while the correction value of the curvature of the scoliotic component remained stable. Intraoperative blood loss in the first group of patients was less (234 mL) compared with that in the second group (319 mL), while the duration of surgery was longer (310 min and 185 min, respectively). On average, in the first group, a longer metal structure was used to correct the spinal deformity compared with the second group.
Conclusions. The correction of the patients' congenital spinal deformities with a single hemivertebra from a combined access approach allows a complete correction of the congenital curvature, the fixation of a smaller number of vertebrae, and the maintenance of a stable result in the long-term observation period compared with the dorsal approach. Isolated dorsal access to the hemivertebral body is characterized by less intraoperative blood loss compared with the combined approach, although the length of surgical intervention is increased.

Keywords: congenital scoliosis; congenital kyphosis; monosegmental spinal malformations; hemivertebrae; hemivertebrae excision; posterior approach; combined approach; correction of the deformity; invasiveness of surgery.

СРАВНИТЕЛЬНЫЙ АНАЛИЗ ХИРУРГИЧЕСКОГО ЛЕЧЕНИЯ ДЕТЕЙ ДОШКОЛЬНОГО ВОЗРАСТА С ВРОЖДЕННОЙ ДЕФОРМАЦИЕЙ ПОЗВОНОЧНИКА ПРИ ИЗОЛИРОВАННЫХ ПОЛУПОЗВОНКАХ ИЗ КОМБИНИРОВАННОГО И ДОРСАЛЬНОГО ДОСТУПОВ

© *С.В. Виссарионов[1], А.Р. Сюндюков[2], Д.Н. Кокушин[1], Н.О. Хусаинов[1], М.А. Хардиков[1]*

[1] ФГБУ «Научно-исследовательский детский ортопедический институт им. Г.И. Турнера» Минздрава России, Санкт-Петербург;
[2] ФГБУ «Федеральный центр травматологии, ортопедии и эндопротезирования» Минздрава России, Чебоксары

■ Для цитирования: Виссарионов С.В., Сюндюков А.Р., Кокушин Д.Н., и др. Сравнительный анализ хирургического лечения детей дошкольного возраста с врожденной деформацией позвоночника при изолированных полупозвонках из комбинированного и дорсального доступов // Ортопедия, травматология и восстановительная хирургия детского возраста. – 2019. – Т. 7. – Вып. 4. – С. 5–14. https://doi.org/10.17816/PTORS745-14

Поступила: 12.07.2019 Одобрена: 01.12.2019 Принята: 09.12.2019

Обоснование. В настоящее время проведено достаточное количество исследований, посвященных оценке результатов оперативного вмешательства и сравнительному анализу различных хирургических методик лечения детей с врожденной деформацией позвоночника. Однако не существует единого мнения в отношении выбора хирургического доступа к аномальному позвонку с учетом длительности операции, объема интраоперационной кровопотери, величины достигнутой коррекции в ходе вмешательства, протяженности металлофиксации и сохранения полученного результата в отдаленном периоде наблюдения.

Цель — выявить преимущества и недостатки дорсального и комбинированного доступов к хирургическому лечению детей дошкольного возраста с врожденной деформацией грудного и поясничного отделов позвоночника на фоне изолированного нарушения формирования позвонка.

Материалы и методы. Проведен ретроспективный анализ лечения 56 пациентов в возрасте до 5 лет с врожденными деформациями позвоночника на фоне изолированного полупозвонка в грудном и поясничном отделах, которым выполняли одноэтапную экстирпацию полупозвонка из дорсального (1-я группа; $n = 30$) или комбинированного (2-я группа; $n = 26$) доступа.

Результаты. У всех пациентов было отмечено улучшение сагиттального и фронтального профилей позвоночника. Однако в отдаленном периоде у пациентов 1-й группы наблюдалось прогрессирование кифотического компонента деформации в поясничном отделе позвоночника с −19 до −8°, при этом величина коррекции сколиотического компонента искривления оставалась стабильной. Интраоперационная кровопотеря в 1-й группе пациентов была меньше (234 мл по сравнению с 319 мл во 2-й группе), при этом операции длились дольше (310 и 185 мин соответственно). В 1-й группе для коррекции деформации позвоночника использовали в среднем более протяженную металлоконструкцию по сравнению со 2-й группой.

Заключение. Коррекция врожденной деформации позвоночника у пациентов с единичным полупозвонком из комбинированного доступа позволяет достичь полноценного исправления врожденного искривления с фиксацией меньшего количества позвонков, при этом стабильный результат сохраняется в отдаленном периоде наблюдения в отличие от дорсального подхода. Изолированный дорсальный доступ к телу полупозвонка отличается меньшей интраоперационной кровопотерей по сравнению с комбинированным, однако время хирургического вмешательства в случае изолированного дорсального доступа больше.

Ключевые слова: врожденный сколиоз; моносегментарные пороки позвоночника; экстирпация полупозвонка; дорсальный доступ; комбинированный доступ; коррекция деформации; травматичность операции.

Abnormalities in the vertebral development often cause the onset and progression of congenital deformity of the spinal column during the growth and development of a child. The prevalence of vertebral malformations is 1 per 1,000 newborns [1]. One of the most common malformations of the spine, leading to severe and rigid curvatures already in preschool age, is a vertebral malformation [2].

With the development of pediatric vertebrology, various options have been developed for surgical interventions and tactical approaches aimed at correcting congenital curvature using a multi-support spinal system. In recent years, studies have appeared focused on assessing the results of the correction of congenital deformity in various approaches and the comparative analysis of their effectiveness, both by Russian and international authors [3–6].

Analyzing the work that deals with the surgical treatment of patients with congenital spinal deformity, we cannot but notice the lack of consensus on the optimal surgical approach to the body of the abnormal vertebra during surgical treatment of pediatric patients with this pathology. Some authors prove the possibility of optimal correction of congenital spinal deformity only from the dorsal access [7–10], whereas others argue that the best results are obtained from combined access (anterolateral and dorsal) [4, 11–14]. At the same time, the issue of the extent of metal fixation remains open for various options of surgical approach in the treatment of pediatric patients with congenital spinal curvature. Some authors believe that the correction of congenital deformity should be performed by fixing the minimum number of spinal motion segments and stabilizing only neighboring vertebrae relative to the abnormal one [5, 15, 16].

Others argue that the correction of congenital deformity must be performed by multi-support hardware with fixation of the vertebrae located over several spinal motion segments above and below the vicious vertebra [11]. However, no study provides a comparative analysis of the number of stabilized spinal motion segments using the spinal system for various surgical approaches for the correction of congenital deformity in pediatric patients.

Intraoperative blood loss during surgical treatment of pediatric patients with congenital spinal deformities, despite the improvement of intervention methods and the use of modern special means for hemostasis during surgery, is an inevitable adverse event. The main causes of intraoperative blood loss during surgical correction of congenital curvature of the spinal column include soft tissue injury, impaired integrity of the posterior bony structures of the spine, bleeding from the vessels of the spinal canal, increased pressure in the vessels of the inferior vena cava system due to the patient's non-physiological position, and duration of the intervention [17–19].

Thus, the problem of choosing the most rational surgical approach and its effectiveness in correcting congenital spinal deformity in pediatric patients remains unresolved.

This study aimed to identify the advantages and disadvantages of the dorsal and combined approaches to surgical treatment of preschool pediatric patients with a congenital deformity of the thoracic and lumbar spine with an isolated malformation of the vertebra.

Materials and methods

Study design

This is a comparative intergroup retrospective study with bicenter enrollment into groups.

The material of the study was the medical history, examination results, and surgical treatment of 56 pediatric patients aged 1 to 5 years (26 girls and 30 boys) with congenital spinal deformity with an isolated segmented semivertebra of the thoracic or lumbar region. The average age of the patients was 4 years and 8 months. The semivertebra was located in the thoracic region (Th_5–Th_{12}) in 34 patients and the lumbar region (L_1–L_4) in 22 patients. Depending on the surgical access, two groups were formed. Patients in Group 1 (n = 30) underwent the surgical intervention from the dorsal access, and combined access was performed for patients in Group 2 (n = 26). The average follow-up period in the long term was 5 years and 10 months (from 2 years and 3 months to 7 years).

Inclusion criteria

Inclusion criteria are as follows: the presence of a single defect in the thoracic or lumbar region, the absence of neurological disorders in the clinical presentation, simultaneous monosegmental extirpation of the semivertebra and correction of congenital deformity using the surgical hardware, and the age of patients at the time of surgical treatment (1 to 5 years). Patients had a mesosomatic somatotype with harmonious or disharmonious development. The informed consent of the patient representative to participate in the study was obtained. *Exclusion criteria* were multi-stage surgical treatment, multiple malformations of the spine, neurological disorders in the clinical presentation, pathological changes in the spinal cord according to magnetic resonance imaging, and somatic diseases in the stage of decompensation.

Study conditions

All pediatric patients received surgical treatment in a planned manner in the departments of pathology of the spine and neurosurgery of the Turner Scientific Research Institute for Children's Orthopedics, and the children's traumatology and orthopedic department of the Federal Center for Traumatology, Orthopedics, and Endoprosthetics (Cheboksary) from January 2011 to January 2017 inclusive, under the agreement on scientific and practical cooperation, which provides the opportunity for the surgery to be conducted by specialists of one institution in another institution.

Research methods

Clinical and laboratory examination included an assessment of orthopedic and neurological statuses. In addition, the duration of the surgical session (in minutes), the volume of intraoperative blood loss (absolute in milliliters and relative in percent of the volume of circulating blood), the amount of correction of congenital deformity during the surgery, the length of the hardware fixation, and the long-term stability of the treatment result were also taken into account. In all pediatric patients, anatomical and anthropometric parameters, growth, and weight indicators were evaluated before surgery.

All patients underwent radiation examination (X-ray imaging in two projections in the standing position, multispiral computed tomography, and magnetic resonance imaging) of the spine before surgery, after surgery, and in the long-term postoperative period during case follow-up with a frequency of one time in 6 months and then once a year. Radiographs determined the local scoliotic and kyphotic components of spinal deformity according to the Cobb method before surgery, the amount of correction after it, and the stability of the result achieved in the process of further development of the child.

The surgical treatment techniques were the extirpation of a single semivertebra together with the upper and lower intervertebral disks and the correction of congenital deformity of the multi-support transpedicular surgical hardware, followed by the creation of posterior local spine fusion and fusion. All surgeries were performed by one surgical team. This approach to the inclusion of patients in the study group provided more reliable data. Moreover, specialists of each institution, regardless of each other, performed several dozen such surgical interventions every year in pediatric patients with congenital spinal deformities. The groups under study were formed retrospectively, depending on the surgical access to the abnormal vertebra during the study period. In the presence of a pronounced bone block formed in the surgery area, the surgical hardware was removed in 1.5–2 years after the surgery. After that, the case follow-up was continued for the patients with X-ray control one time per year.

Intraoperative blood loss was evaluated by the gravimetric method and by determination of blood volume aspirated into a graduated container for blood. The circulating blood volume (CBV) was determined by the following formula: CBV = bodyweight of the child (kg) × coefficient X (for pediatric patients under 6 years of age $X = 80$ mL/kg) [20]. To reduce intraoperative blood loss, biological and technical blood-saving techniques were used [1, 5, 21, 22].

Statistical analysis was performed using the Statistica 13 program (StartSoftInk, USA). The arithmetic mean (M) and the mean deviation ($\pm m$) were calculated. The normality of the distribution of parameters was checked using the coefficient of variation, mean absolute deviation, range of variation, asymmetry, and kurtosis parameters. To determine the statistical significance of differences in paired measurements, the paired Student t-test was used, and the results were considered significant at $p < 0.05$. To determine the linear relationship, the Pearson correlation criterion (r) was used. The significance of differences between the means was evaluated by comparing variances.

Results

The patients were divided into two groups depending on the version of the surgical approach to the body of the abnormal vertebra. But the patients of both groups did not differ in age or localization of the semivertebra (Table 1).

In patients of both groups, local curvature in the thoracic or lumbar region was manifested as both scoliotic and kyphotic components of spinal deformity (Table 2).

The indication for surgical correction of spinal curvature was congenital spinal deformity with local pathological scoliosis of more than 20° in combination with a kyphotic component of curvature of more than 8° in the lumbar region and more than 18° in the thoracic region [15, 16].

It should be noted that the value of the scoliotic component of deformity in both groups of patients was almost equal, whereas the value of local kyphosis at the level of the abnormal vertebra in Group 2 was significantly higher than that in Group 1 ($p = 0.02$

Table 1

Characteristics of study groups by age and localization of congenital malformation

Group	Number of patients	Age at time of surgery (months)	Semivertebra localization	
			Thoracic region	Lumbar region
1	30	36.5 ± 11.6	19	11
2	26	44.2 ± 10.4	15	11

Table 2

Indicators of scoliotic and kyphotic deformities before surgery in patients of the two groups

Deformity component	Group	Initial spinal deformity, in degrees by Cobb			
		Thoracic region		Lumbar region	
Local scoliotic component, $M \pm m$	1	26.3 ± 2.8	$p = 0.04$	22.0 ± 2.1	$p = 0.05$
	2	23.4 ± 2.9		22.5 ± 3.1	
Local kyphotic component, $M \pm m$	1	28.4 ± 1.9	$p = 0.02$	22.0 ± 3.1	$p = 0.05$
	2	35.2 ± 2.3		28.9 ± 2.7	

Table 3

Indicators of the duration of surgical intervention and the volume of blood loss depending on surgical access

Group	Localization of deformity	Duration of surgery (min)		Intraoperative blood loss			
				Absolute, mL		Relative, percentage of CBV	
1	Thoracic region	310 ± 22* (min 185; max 460)	307 ± 21 (min 240; max 425)	234 ± 34* (min 50; max 600)	220 ± 41 (min 50; max 500)	16.7 ± 0.9* (min 3.5; max 52.5)	15.5 ± 1.1 (min 3.5; max 42.9)
	Lumbar region		313 ± 40 (min 185; max 460)		252 ± 61 (min 50; max 600)		17.9 ± 1.5 (min 5.7; max 52.5)
2	Thoracic region	185 ± 13* (min 155; max 230)	192 ± 20 (min 165; max 230)	319 ± 25* (min 140; max 650)	327 ± 41 (min 150; max 650)	20.2 ± 1.0* (min 4.7; max 54.6)	23.2 ± 1.6** (min 7.4; max 54.6)
	Lumbar region		175 ± 20 (min 155; max 220)		293 ± 34 (min 140; max 550)		17.3 ± 1.2** (min 4.7; max 45.8)

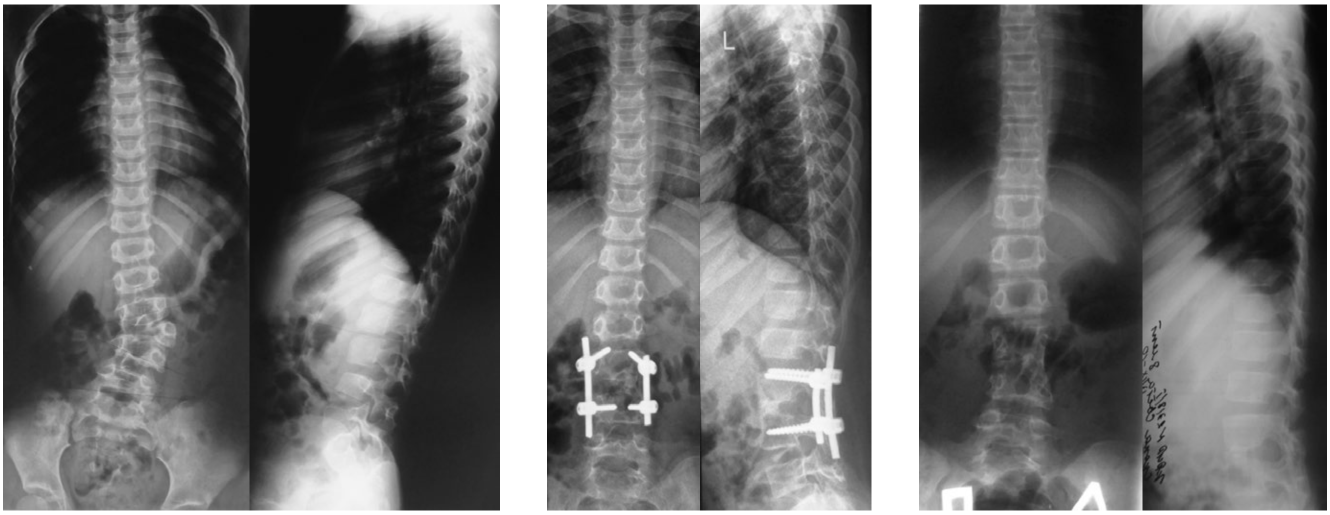
Note. *$p < 0.05$ for Groups 1 and 2; **$p < 0.05$ for the thoracic and lumbar spine within the group. CBV, circulating blood volume.

and $p = 0.05$, respectively). However, the analysis of variance revealed the absence of significant differences between the average values of the comparison groups.

The study revealed the dependence of the duration of the surgical intervention on access to the body of the abnormal vertebra. With the dorsal approach, the average duration of the surgery was 310 min (min 185; max 460), and with the combined approach, it was 185 min (min 155; max 230; significant increase, $p = 0.001$). The volume of blood loss after surgery in Group 1 was 234 mL (min 50; max 600), which corresponds to 16.7% of the CBV, and in Group 2, it was 319 mL (min 150; max 650), which is 20.2% of the CBV. Also, a statistically significant decrease in both absolute and relative intraoperative blood loss was revealed in Group 1 compared with that in the comparison group ($p = 0.04$ and $p = 0.01$, respectively). In Group 2, the volume of intraoperative blood loss was significantly higher with the localization of the vicious vertebra in the thoracic region than with the location of the semivertebra in the lumbar region ($p = 0.007$). A pronounced inverse correlation was established between the duration of the surgery and the volume of blood loss with high binding strength ($r = -0.871$). The results of the surgery duration and the amount of blood loss during the intervention are presented in Table 3.

After surgery in patients of both groups, a radical correction of both the scoliotic and kyphotic components of the deformity was achieved with the restoration of physiological profiles of the spine. The insignificant residual value of the deformity, as well as the difference in the measurement of correction indicators between the groups and in the long-term follow-up period, corresponded to the values of the measurement error. As a result of the surgery, it was possible to restore the sagittal profile of the deformed spinal motion segment (Figure).

However, in the long-term period after surgery, a progression of the kyphotic component of the



a *b* *c*

Radiographs of patient K., 1 year and 3 months, with congenital kyphoscoliosis with posterolateral semivertebra: (*a*) before surgery, the scoliosis angle is 26°, and the kyphosis angle is 12°; (*b*) 1.5 years after the surgery from a combined approach; and (*c*) 6 years after removal of surgical hardware

Table 4

Changes in correction of spinal deformity

Group	Localization of deformity	Average number of blocked vertebrae	Postoperative deformity of the spine (°)		Deformity in the long-term follow-up period (°)	
			Local scoliotic component	Local kyphotic component	Local scoliotic component	Local kyphotic component
1	Thoracic region	3.3	5	7	0	7
	Lumbar region	3.1	5	–19	2	–8
2	Thoracic region	3.0	5	5	2	5
	Lumbar region	2.8	8	–16	0	–16

deformity in the lumbar spine from –19° to –8° ($p = 0.04$) was noted in the group of patients operated only from the dorsal access, while the correction value of the scoliotic component of the curvature remained stable throughout the entire period. At the same time, it should be noted that the achieved correction of deformity after surgery remained stable during the long-term follow-up period in patients using a combined approach. During the surgery, correction was achieved by stabilizing a larger number of vertebrae in Group 1 compared with that in the comparison group. This result was because dorsal access did not provide a sufficiently good and complete visual view and achieve full mobility in the intervention zone. The results are presented in Table 4.

Verticalization was performed on average on the fifth and seventh days after the surgery in Groups 1 and 2, respectively ($p = 0.02$); setting on the legs was performed when the child's condition stabilized, and the pain was relieved.

Discussion

Current trends in vertebrology imply an increasing use of dorsal access in surgery for monolesions of the thoracic and lumbar spine in pediatric patients [4]. These changes are associated with the evolution of surgical technique and the introduction of contemporary pediatric spinal systems of transpedicular fixation. Both Russian and international authors consider the main advantages of dorsal access to reduce the surgery duration, intraoperative blood loss, and rehabilitation period [3, 7, 10].

The study revealed that in case of only dorsal access to correct congenital spinal deformity against an isolated malformation of the vertebra in the thoracic or lumbar spine, the time of surgery significantly increased compared with the combined approach. We explain the increase in the time of surgical intervention with the dorsal approach compared with combined access to the need for additional mobilization of the dural sac with its contents for optimal visualization of the approach to the abnormal vertebra. Extended dorsal access with resection of the head and the proximal section of the rib (costotransversectomy) did not provide a full visual view of the intervention area, which, of course, contributed to an increase in the surgery duration. Many researchers also emphasize the disadvantages of the dorsal approach, which include the lack of optimal control over the structures of the spinal canal and the impossibility of resection of a part of the disk on the concave side of the deformity [8]. From our point of view, the limitedness of the isolated dorsal approach causes technical difficulties in removing the disk apparatus on the side opposite to the abnormal vertebra (which is necessary to achieve full mobility in the area of the defect) and affects the duration of the surgical intervention.

It was noted that the absolute and relative values of the volume of blood loss were significantly higher in patients using a combined approach compared with the dorsal one. This was primarily due to the presence of two accesses in Group 2 compared with that in Group 1. It should be noted that when using the anterolateral approach, simultaneous massive bleeding occurred during removal of the endplate of the abnormal vertebra adjacent to the spinal canal and the site of its base of the arc from the vessels of the dural sac. In addition, a greater volume of blood loss in Group 2 compared with that in Group 1 was due to bleeding that occurred when the ligamentous and disk apparatus elements were removed, which was thoroughly removed from the anterolateral access, as well as continued bleeding from the anterolateral approach in patients of these groups when using the dorsal approach and correction of congenital deformity. Performing extirpation of a semivertebra with combined access using traditional technical means that thoracic localization of the defect is associated with a longer surgery duration and blood loss compared with lumbar localization.

When comparing the results of our study with literature data, the analyzed indicators coincided. Thus, Mladenov et al. [23] considered that dorsal access is preferable from the position of minimizing intraoperative blood loss. Peng et al. [7] emphasized that the combined approach reduces the time of surgical intervention with a significant increase in blood loss.

The minimum fixation of the spinal area during correction of congenital curvature is especially relevant and important for patients of the younger age group, which is due to the preservation of the growth potential of the spine [1, 5, 7]. However, at present, there are no works on comparative analysis of the extent of transpedicular metal fixation in correction of congenital spinal deformity made from dorsal and combined approaches.

Our approach to correcting congenital spinal deformity in preschool pediatric patients consists of radical correction of the curvature and stabilization of only the spinal motion segments involved in the main arch. In patients of both groups, we managed to achieve complete correction of congenital deformity. However, during the surgery, it was necessary to resort to fixing a larger number of spinal motion segments in the area of the main curvature arch in both the thoracic and lumbar regions in Group 1 compared with Group 2. The shorter length of metal fixation in patients using the combined approach was explained by the fact that with anterolateral access, it was possible to achieve significant mobility in the intervention area due to the complete removal of not only the bone structures of the abnormal vertebra body but also the adjacent disk and ligamentous apparatus due to the convenience of this approach and good visualization [12, 14, 15]. The anterolateral approach helped achieve complete correction of congenital deformity by stabilizing the minimum number of vertebrae compared with patients who had only dorsal access. Also, in the long-term follow-up period, the progression of the kyphotic component of the deformity in Group 1 was noted.

In our opinion, this was explained by the complexity of performing a full-fledged and stable fusion from the dorsal approach in the same way as in patients of the comparison group. From anterolateral access, it is possible to create and form a more reliable and stable fusion by installing an autograft as a thrust between intact vertebral bodies relative to the abnormal vertebral body. Thus, in the development process, patients in Group 1 had a bone graft subsidence and a significant loss of correction of the kyphotic component of the curvature as compared with the result achieved during the surgery. A comparative analysis of studies on the stiffness of various options for stabilization of the spine shows that isolated posterior spine fusion does not adequately ensure complete immobilization of the spine [24]. The resulting pathological changes in the blocked vertebrae, as well as excessive loads on the vertebrae that are in contact with this fixation zone, often lead to certain progression of spinal deformity. It should be emphasized that the use of interbody allograft enables to save the achieved correction of deformity in the long-term postoperative period.

Conclusion

Thus, because of the combined approach, it is possible to achieve complete correction of congenital deformity in the thoracic and lumbar regions of preschool patients, with fixation of a smaller number of vertebrae compared with the dorsal access. Isolated dorsal access in the correction of congenital spinal deformity in the thoracic or lumbar spine in preschool pediatric patients enables to reduce the amount of blood loss during surgery, while the time of the intervention itself is increased compared with the combined approach. Also, the achieved result in the long-term postoperative period was preserved in the group of patients using combined access due to the formation of reliable and pronounced anterior and posterior bone blocks.

Additional information

Funding. The study was performed in accordance with state contract No. K-27-NIR/111-1 for research within the framework of the Union State program "Development of new spinal systems using prototyping technologies in surgical treatment of pediatric patients with severe congenital deformities and spinal injuries."

Conflict of interest. The authors declare no conflict of interest.

Ethical consideration. The study was approved by the ethics committee of the Turner Scientific Research Institute for Children's Orthopedics (protocol No. 4 of 27.11.2018). Patients and their representatives gave informed consent to participate in the study and publish personal data.

Contribution of authors

S.V. Vissarionov performed surgical treatment of patients, formulated the aim, performed stage and final editing of the article text.

A.R. Syundyukov conducted surgical treatment of patients, collected the data.

D.N. Kokushin performed surgical treatment of patients, stage editing of the article text.

N.O. Khusainov performed literature review, created the article design.

M.A. Hardikov performed data collection and analysis, wrote the article text, created the article design.

All authors made a significant contribution to the research and preparation of the article, read and approved the final version before its publication.

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Information about the authors

Sergei V. Vissarionov — MD, PhD, D.Sc., Professor, Corresponding Member of RAS, Deputy Director for Research and Academic Affairs, Head of the Department of Spinal Pathology and Neurosurgery. The Turner Scientific Research Institute for Children's Orthopedics, Saint Petersburg, Russia. https://orcid.org/0000-0003-4235-5048. E-mail: vissarionovs@gmail.com.

Ayrat R. Syundyukov — MD, PhD, Head of Children's Traumatological and Orthopedic Department of Federal Center of Tpaumatology, Orthopedics and Endoprothesis Replacement, Cheboksary, Russia. https://orcid.org/0000-0001-8276-9216. E-mail: asiundiukov@ortoscheb.com.

Dmitry N. Kokushin — MD, PhD, Senior Research Associate of the Department of Pathology of the Spine and Neurosurgery. The Turner Scientific Research Institute for Children's Orthopedics, Saint Petersburg, Russia. https://orcid.org/0000-0002-6112-3309. E-mail: partgerm@yandex.ru.

Nikita O. Khusainov — MD, PhD, Research Associate of the Department of Pathology of the Spine and Neurosurgery. The Turner Scientific Research Institute for Children's Orthopedics, Saint Petersburg, Russia. https://orcid.org/0000-0003-3036-3796. E-mail: nikita_husainov@mail.ru.

Michael A. Khardikov* — MD, PhD student, Department of Spinal Pathology and Neurosurgery. The Turner Scientific Research Institute for Children's Orthopedics, Saint Petersburg, Russia. https://orcid.org/0000-0002-8269-0900. E-mail: Denica1990@bk.ru.

Сергей Валентинович Виссарионов — д-р мед. наук, профессор, член-корр. РАН, заместитель директора по научной и учебной работе, руководитель отделения патологии позвоночника и нейрохирургии ФГБУ «НИДОИ им. Г.И. Турнера» Минздрава России, Санкт-Петербург. https://orcid.org/0000-0003-4235-5048. E-mail: vissarionovs@gmail.com.

Айрат Рашитович Сюндюков — канд. мед. наук, заведующий детским травматолого-ортопедическим отделением ФГБУ «ФЦТОЭ» Минздрава России, Чебоксары. https://orcid.org/0000-0001-8276-9216. E-mail: asiundiukov@ortoscheb.com.

Дмитрий Николаевич Кокушин — канд. мед. наук, старший научный сотрудник отделения патологии позвоночника и нейрохирургии ФГБУ «НИДОИ им. Г.И. Турнера» Минздрава России, Санкт-Петербург. https://orcid.org/0000-0002-6112-3309. E-mail: partgerm@yandex.ru.

Никита Олегович Хусаинов — канд. мед. наук, научный сотрудник отделения патологии позвоночника и нейрохирургии ФГБУ «НИДОИ им. Г.И. Турнера» Минздрава России, Санкт-Петербург. https://orcid.org/0000-0003-3036-3796. E-mail: nikita_husainov@mail.ru.

Михаил Александрович Хардиков* — аспирант отделения патологии позвоночника и нейрохирургии ФГБУ «НИДОИ им. Г.И. Турнера» Минздрава России, Санкт-Петербург. https://orcid.org/0000-0002-8269-0900. E-mail: Denica1990@bk.ru.